THE DEVELOPMENT AND APPLICATION OF MALAYSIAN UNIVERSITY CAMPUS EMISSION TOOL (MUCET) TOWARDS CREATING SUSTAINABLE CAMPUS

ABDUL-AZEEZ ISIAKA ADEYEMI

UNIVERSITI TEKNOLOGI MALAYSIA

THE DEVELOPMENT AND APPLICATION OF MALAYSIAN UNIVERSITY CAMPUS EMISSION TOOL (MUCET) TOWARDS CREATING SUSTAINABLE CAMPUS

ABDUL-AZEEZ ISIAKA ADEYEMI

A thesis submitted in fulfilment of the
requirements for the award of degree of
Doctor of Philosophy (Urban and Regional Planning)

Faculty of Built Environment
Universiti Teknologi Malaysia

March 2012

Dedicated to my wife, Mrs Muslimat Oyeronke Abdul-Azeez, my children Messrs Rizquat Adeshewa, Jubril Adeshina, Sidiquat Adewumi and Abdul-Azeez Adekunle, and also to my mother Mrs F. A. Adeyemi, my brother Alh Jubril Ajayi and to my late father Alh. Abdul-Azeez Olalekan Adeyemi,

for their support, prayers and understanding.

I am for ever indebted to you all and remain your noble ambassador

ACKNOWLEGEMENT

I wish to express my sincere appreciation to my supervisor, Professor Dr. Ho, Chin Siong, for the encouragement, guidance and criticism, without which this thesis would not have been the same as presented. My sincere appreciation goes to all my colleagues, friends and others whom space will not permit me to mention for the assistance provided at various occasions and for the special kind of friendship extended to me.

I must express my appreciation for the cooperation of the entire members of staff of Faculty Alam Bina. I will also like to thank the staff of the Assets and Facilities Department. (Harta Bina) UTM, particularly Mr Khayrun Nizam, Mr. Sharima, and Mr. Amir Hamza for their cooperation during the data collection for this research, as well as Dr. Hassan Chizari for assisting in the development of MUCET.

I also wish to appreciate the kindness of Prof. Said Idid Abidin, Prof. Mahbob Salim, Prof Rosdan and Dr. Rosli. I could not have anticipated what your support and friendship would mean to me over the course of this journey. In fact you made this process so much bigger than the degree itself and for that I thank you.

This thesis and the topic of university campus sustainability impassioned me. I glorified Allah for the inspiration and thank Dr. Chandrasekhar, for boosting my confidence early in my journey when I desperately needed it. Most of all, I need to extend a special gratitude to Dr. Mohammed Zali Shah for the access given to me, I am truly glad I ventured over to your office to solicit for your assistance and I am very grateful for your contributions.

I also wish to recognize Alh. Jubril Ajayi for his contributions and support, I will forever remain indebted. Finally, I need to thank my mother, Mrs F. A. Adeyemi, my wife, Mrs M. O. Abdul-Azeez and my children for their patience, prayers and love. I certainly share this accomplishment with all of you.

Peace profound!

ABSTRACT

The practice of unsustainable energy use in the university campus results in continuous emission of carbon dioxide (CO_2), a predominant global warming greenhouse gas (GHG). Achieving emission-free campus environment infers the reduction of CO_2 emission, through the analysis of the sources, types and the extent of emission on the campus. Existing carbon emission calculators are cumbersome, complex and not easily understood by university administrators and require background knowledge of environmental science to interpret the results. This study investigates the pattern of energy currently in use within Universiti Teknologi Malaysia (UTM) main campus with a view to determine the sources of emission of carbon dioxide from operations in the campus. The study identified two types of energy consumption - electricity and transport and five (5) major service demand sectors of energy use. Energy use data were collected from the transport and electricity sectors in the campus, and a prototype carbon calculator called the Malaysian University Campus Emission Tool (MUCET) was developed and applied to determine the extent of emission from each service sector. It was observed that the Teaching and Learning sector constitutes 31% of total carbon emission followed by the Transport sector with 26%. Students' hostels has 22%, while the Information and Communication Technology sector and the Administrative and Support Services sectors have 11% and 10% of total CO_2 emission respectively. Finally, MUCET can be used for CO_2 assessment in other universities to present the emission scenarios as well as facilitate the setting of targets to reduce CO_2 emission. In conclusion, the study suggested mitigation strategies such as energy efficiency, behavioural changes and the use of bio-fuels to combat carbon emission in UTM. Also, the need for cooperation and collaboration in terms of emission reduction among Malaysian universities was recommended as a key step to promote university campus energy sustainability.

ABSTRAK

Amalan menggunakan tenaga bukan lestari dalam kampus universiti menyebabkan pengeluaran berterusan karbon dioksida (CO_2), yang merupakan gas rumah hijau pemanasan global yang dominan (GHG). Mendapatkan persekitaran kampus yang bebas pelepasan CO_2 membawa kepada cadangan pengurangan pelepasan CO_2 melalui analisis terhadap punca, jenis dan tahap pelepasan gas tersebut didalam kampus. Pengira bagi mengukur pelepasan karbon yang ada sekarang ini adalah rumit, kompleks dan tidak mudah difahami oleh pentadbir universiti. Ia memerlukan pengetahuan asas tentang sains alam sekitar bagi mentafsirkan keputusannya. Kajian ini menyiasat corak atau pola penggunaan tenaga di kampus induk Universiti Teknologi Malaysia (UTM) dengan hasrat untuk mengenalpasti punca pelepasan karbon dioksida dari operasi kampus. Kajian ini mengenalpasti dua (2) jenis penggunaan tenaga di UTM, iaitu letrik dan pengangkutan serta lima (5) sektor pengguna tenaga yang memerlukan perkhidmatan. Data penggunaan tenaga dikutip dari sektor pengangkutan dan letrik dalam kampus UTM dan kaedah prototaip pengiraan karbon yang dipanggil "the Malaysian University Campus Emission Tool atau MUCET" telah dibangun dan digunakan bagi menentukan tahap pelepasan gas bagi setiap sektor perkhidmatan. Adalah di dapati bahawa sektor Pengajaran dan Pembelajaran menyumbang sebanyak 31% daripada jumlah pelepasan karbon didalam kampus UTM. Ia di ikuti oleh sektor Pengangkutan sebanyak 26%. Asrama pelajar pula menyumbang sebanyak 22% sementara sektor Teknologi Maklumat dan Komunikasi serta Sektor Pentadbiran dan Perkhidmatan Sokongan pula menyumbang sebanyak 11% and 10% daripada jumlah pelepasan karbon. MUCET juga boleh digunakan bagi mengukur pelepasan CO_2 di kampus universiti lain bagi menggambarkan senario pelepasan serta membantu menetapkan sasaran bagi pengukuran pelepasan CO_2. Kesimpulannya, kajian ini mencadangkan strategi pengurangan pelepasan seperti kecekapan tenaga, perubahan sikap dan penggunaan bahan api-bio bagi menangani pelepasan karbon dalam UTM. Selain dari itu adalah di sarankan supaya diadakan kerjasama dan kesepakatan dikalangan universiti di Malaysia untuk mengurangkan pelepasan karbon sebagai salah satu usaha utama menggalakkan kelestarian penggunaan tenaga kampus universiti.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AASHE	-	Association for the Advancement of Sustainability in Higher Education
ACUPCC	-	American College & University Presidents' Climate Commitment
AEUI	-	Annual Energy Use Index
ALU	-	Agricultural and Land Use National Greenhouse Gas Inventory Software
AUCC	-	Association of Universities and Colleges of Canada
BREEAM	-	British Research Establishment Environmental Assessment Methods
CA-CP	-	Clean Air Cool Planet
CalCAP	-	California Climate Action Partnership
CARROT	-	Climate Action Registry Reporting Online Tool
CO_2	-	Carbon Dioxide
CSAF	-	Campuses Sustainable Assessment Framework
eGGRT	-	Electronic Greenhouse Gas Reporting Tool
EMAS	-	Environmental Management and Audit Scheme
EPA	-	United State Environmental Protection Agency
ESD	-	Energy Statistics Division
ETC	-	Employee Transportation Coordinators
GHG	-	Greenhouse Gas
GRAPE	-	Goal Research Analysis Planning and Effectuation
GWP	-	Global Warming Potential
HED	-	High Electricity Demand
IEA	-	International Energy Agency
IPCC	-	Intergovernmental Panel on Climate Change

ISCN	-	International Sustainable Campus Network
kCO_2	-	Kilogram of Carbon Dioxide emissions.
LCA	-	Life Cycle Assessment
LEED	-	Leadership in Energy and Environmental Design
LRDP	-	UC Berkeley's 2020 Long Range Development Plan
MOHE	-	Ministry of Higher Education
$MtCO_2$	-	Metric ton of carbon dioxide equivalent emissions.
MUCET	-	Malaysian University Carbon Emission Tool
MWh	-	megawatt hour
NJHEPS	-	New Jersey (USA) Higher Education Partnership for Sustainability
PTD	-	Pneumatic Traffic Detector
PTM	-	Pusat Tenaga Malaysia
SCMP	-	Strawberry Creek Management Plan
STARS	-	Sustainability Tracking Assessment and Rating System
SYC	-	Sierra Youth Coalition
TNB	-	Tenaga Nasional Berhad
UCOP	-	University of California "Policy on Sustainable Practices"
ULSF	-	University Leaders for Sustainable Future
UNCED	-	United Nations Conference on Environment and Development
UNDESA	-	United Nations Department of Economic and Social Affairs
WCED	-	World Commission on Environment and Development
WRI	-	World Resources Institute
WSSD	-	World Summit on Sustainable Development
WVO	-	Waste Vegetable Oil
WWF	-	World Wildlife Fund

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

Introduction

In the light of current problems of environmental sustainability and global warming issues, planning sustainable university campus through reduction of emission of carbon dioxide from energy use is desirable. The Intergovernmental Panel on Climate Change (IPCC) of the United Nation issued a consensus report (IPCC, 2007) that the main causes of climate change was human activities and predicted that continued buildup of carbon dioxide and other greenhouse gases would cause a rise in global temperature and sea levels.

The concern for global warming is therefore associated with CO_2 emission from energy, and focuses on the potential of the university campus to establish new thinking about energy use by way of research programs, investment decisions and training directed towards the management of energy use to reduce carbon dioxide emission. This research considers the carbon emission from energy use within the university campus environment and also identifies planning issues affecting the performance of the university campus in relation to sustainability and global warming.

For decades a number of International sustainability declarations directed at higher education institutions existed, among which are the Stockholm Declaration (1972), the Talloires Declaration (1990), and the Kyoto Declaration (1993) to

mention a few. Current actions being taken on campuses show that environmental sustainability is not entirely new to universities. However the approach and tools of assessment differ in the criteria considered for rating which ranges from site planning, water efficiency, health and comfort, land use and ecology, economy, energy efficiency, service quality and waste management.

This broad nature of sustainability goals permitted a range of diversity in its perception, resulting into series of interpretations about sustainability goals. However, the main focus today is on the potential of the university campus to establish new thinking about energy use, to save cost and reduce their global warming impact through reduction of carbon dioxide emission.

According to Hardy (2008), nations are setting targets to reduce carbon emissions, groups are also getting together to live more sustainably and individuals are making their own lifestyle changes. Carbon emission inventory has become the trend in most countries and universities worldwide are now seeking ways to reduce their emission of greenhouse gases (GHG) by making inventory and setting emission targets. This may assist to combat the consequent ecological catastrophe of the increasing global warming due to increasing population in the universities which imply increase in energy consumption and continuous emission of carbon dioxide owing to the consumption of fossil fuel-based energy.

This chapter looks at the background of the study with an emphasis on global warming concerns and sustainability initiatives of university campus towards reduction of carbon emission. The problem statement describes the issues of energy use and the barriers to university campus sustainability, while the chapter also presented the objectives, scope and significance of this study. Finally, an outline of the thesis content is described.

1.2 Background of the Study

Human activity and practices require energy for lighting, cooling and other domestic purposes as well as for movements and manufacturing and to sustain life. However, some sources of energy usually place stress on the environment and result in the emissions of carbon dioxide and other greenhouse gases (GHG) which impacts negatively on the global environment and require attention. The current problems of global warming require the involvement of the university through the reduction of carbon dioxide emission from energy use in the campus.

The university plays significant role in human development and economic growth by imparting knowledge and grooming the graduates (Rosan, 2002, Greenspan, 2003). Also, universities are among larger developers of communities (Knox, 2002), where new buildings such as classrooms, offices, dormitories, or research spaces are regularly constructed. The activities of the university encourage high population concentration which requires energy for operation, processing and lighting and also attracts high vehicular traffic resulting in high energy consumption.

Global warming is credited to increasing carbon emission from energy consumption by human activities and the current technological practices that favor the use of fossil fuels as major sources of energy (IPCC, 2007). The university becomes relevant in view of considerably high impact of higher institutions of learning on the environment as well as the potentials that can be developed to model sustainable energy use and low carbon emission within the campus. Therefore combating climate change, and cutting carbon emissions, is a predominant environmental challenge, and measuring a university's carbon emissions is a key environmental criterion.

The impact of the energy use for the activities and operations of universities on the environment made campus sustainability an issue of concern, because the majority of the energy source today is fossil fuel based and the high energy consumption in most universities result in high carbon emission

Universities feature large concentrations of population, many of whom work, live, learn and recreate on the campus (Rappaport, 2008). Meanwhile, the use of classrooms, laboratories, offices and catering for activities of the university have direct impacts on the environment, while indirect activities such as the consumption of food and drink at work by students and employees also generate negative environmental impacts (Lukman, 2009). Therefore the large physical and demographic sizes of the university campuses, as well as electricity consumption in operating machines and transportation fuels, result in high emission of carbon dioxide (Alshuwaikhat and Abubakar, 2008). These have serious implication on environmental quality.

The resources consumed by the global university population and educational institutions are very high. For instance there are over 13,000 Higher Education Institutions worldwide (Webometrics, 2009), about one-third of this population are based in Europe having a student population of over 18 million (Eurostat, 2009). Similarly, about 17 million students enrolled in 4,200 colleges and universities in the United States (Rappaport, 2008). Therefore improving the collective environmental performances associated with CO_2 emission from energy use, of colleges and universities could have long-term influence and the effect on global warming may be vast.

The assessment of the environmental implications of university activity on university campus is not uncommon (Velazquez, et al., 2006). Universities can make significant impact in promoting a sustainable future (James, 2009) through the measurement of carbon dioxide emission. It is believed that the implementation of sustainable practice in the university campus is one method of addressing the global climate change (Pepple, 2009), therefore Cortese (2005) proposed the engagement of universities in environmental sustainability experimentation. Never the less, this research believes that environmental sustainability can be better realized when common criteria such as carbon emission from energy use are assessed and adequately measured among the universities.

Based on the potentials of the university campus to establish new thinking about sustainability, recent literature are focusing more attention on the relevance of the carbon emission to global warming (*State of the World*, 2009). Similarly, evolving trend of global warming efforts and initiatives among universities include Sustainable Campus Management (Alshuwaikhat & Abubakar, 2008, Clarke, et al., 2006), Ecological Footprint (Flint, 2001, Stewart, 2005), Inventories of Greenhouse Gas Emission and Carbon Reduction (Isham, 2003, Elderkin, 2007) among others.

Recent concerns are associated with global warming and CO_2 emission from energy use. The growing interest among universities campus environment, and evolving concept view carbon emission reduction as an important tool to aid the shift to sustainability (Pappaport 2008). Therefore majority universities are undergoing a wave to reduce the environmental effects of campuses by reducing energy consumption and carbon emission in the universities (Lukman, 2009, James, 2009).

Universities worldwide are challenged to take up leadership positions in sustainability (ULSF, 2008). Currently, most university sustainability initiatives are anchored on the management of the energy sector and aim to reduce their emission of carbon dioxide, which is regarded as the major driving force for global warming. Unlike in Malaysia, setting emission targets as ways to reduce global warming impacts through carbon dioxide and other greenhouse gases (GHG) emissions in most universities is common in US, UK and Canada among others.

Examples of the initiatives to reduce global warming impacts of university campuses include the Carbon Neutrality, in Middlebury College, Building Environmental Sustainability, Bowling Green State University, Ohio; Ecological Footprint Calculation, University of Toronto Mississauga, Canada; Sustainability Plan of Maharishi University, IOWA; Yale Greenhouse Gas Reduction Strategy; and the Campus Sustainability Assessment, University of California, Berkeley among others. However, this trend of sustainability assessment is yet to be popular among Malaysian universities in view of local barriers and other criteria.

The need to limit the increasing global warming and prevent dangerous climatic change is critical (Hare 2009). But reducing or halting global warming requires the measurement and determination of the existing levels of CO_2 emission so as to manage and effectively plan the reduction. This requires the assessment of the energy use resources. Furthermore, existing environmental sustainability assessment tools are diverse in the criteria considered for rating (Appendix A).

Similarly, evolving concepts of measurement and assessment such as Life Cycle Assessment (LCA), Ecological Footprint, and Carbon Footprint (Conway et al. 2008, Velazquez, L. et al., 2008, Flint, 2001) among others, are also not popular among Malaysian universities. Although these concepts are acceptable for the assessment of environmental performance (Flint, 2001; Venetoulis, 2001; Dawe et al., 2004; Wright, 2002, Stewart 2005), their uses often require expert knowledge in environmental sciences to understand and interpret results for purpose of planning and implementation by university administrators.

Notwithstanding, university campus initiatives are increasingly directed towards assessing the impact of university operations on the climate and global initiatives are directed towards sustainability (Dennis Hardy, 2008), which is rapidly moving from an abstract concept to a measurable state of dynamic human-ecological systems (Mayer, 2008). Recent developments in university campus sustainability assessment are also measuring and assessing environmental and carbon footprint. Therefore, setting targets to reduce emission of CO_2 in the university is a measure of campus sustainability (Greadel, 2002) and regarded as a step towards reducing contribution of the campus to global warming.

It is evident today that carbon emission is a common global sustainability issue as a result of fossil fuel based energy consumption, (Hardy, 2008, Arrow, 2007, Pope et al, 2004), because energy connects everything to everything else more universally and more quantifiably than any element (Jiusto, 2003). Therefore energy is central to sustainability and there cannot be sustainable university development without sustainable energy development.

Colleges and universities have been at the forefront in addressing sustainability and global warming issues through innovative energy use, energy conservation practices and clean power technologies (Eagan, et al., 2008). A similar effort to achieve sustainability among universities is the American College and University Presidents' Climate Commitment (ACUPCC) through an initiative challenging institutions to quantify, reduce and ultimately eliminate their greenhouse gas emissions.

Consequently, other universities are grouping together to form partnerships to pursue the goals of sustainability. For instance the New Jersey (USA) Higher Education Partnership for Sustainability – (NJHEPS) in 2008, was also committed to reducing the greenhouse gas emissions and promoting positive changes in the environment of member universities.

Despite a growing interest among universities towards sustainability initiatives and partnership the tendency among Malaysian universities is to embark on individual approach to sustainability. Some of the initiatives include the Greening the Office in Universiti Sains Malaysia (USM), the Land Green Program in UKM to Create Awareness of Climate Change, World Green Metric Rating of Universiti Putra Malaysia (UPM), and Campus Sustainability initiatives of Universiti Teknologi Malaysia (UTM) in areas, of Socio-cultural, Economic and Eco-system Policies. Therefore, other universities do not benefit from such sustainability initiatives and actions or from the lessons learnt due to the absence of collaboration on sustainability goals.

However, the potential to model the transition to a low-carbon future and facilitate the practice of energy sustainability would require a tool to measure the carbon emission from energy use related sources in the campus in a manner easier to understand by university administrator so as to set target and guidelines to achieve campus sustainability among Malaysian universities.

Also, there is a need to specifically encourage collaboration and partnership on sustainability goals among Malaysian universities by assessing the impact of the operations of the universities on global warming, and determining the amount of

carbon emission from energy use within the university campus. This may offer the opportunity for benchmarking and setting targets to reduce the global warming potential of the universities as well as improve environmental performance and also inculcate sustainability awareness among the students.

This study uses Universiti Teknologi Malaysia (UTM) as case study and identifies unsustainable energy practices as a current planning issue and the absence of carbon emission measuring tool as a barrier affecting the performance of Malaysian universities towards reducing carbon emissions in their campuses. It therefore proposed and developed the Malaysian University Carbon Emission Tool (MUCET) as a means to determine the extent of carbon emission from the university operations, simulate and predict emission for future university developments, as well as to achieve improved environmental condition.

Finally, the study recommended mitigation strategies as a preliminary approach to solving energy sustainability problem in Malaysian university campus, and also proposed behavioral and the use of renewable energy sources while indicating that establishing partnership and collaboration would be most effective approach to achieve sustainability goals among the nation's universities.

1.3 The Rationale of the Study

This research was motivated by the need to achieve university campus sustainability in Malaysia. Similar studies previously investigated the 'Energy Management Key Practices for Universities in Malaysia' (Low S. T. 2008), 'Perception of UTM's Community towards Sustainable Campus' (Gobi, K. A., 2009), 'Factors of Sustainability for UTM Campus Initiatives' (Nurulain. Binti A. Jalal, 2010), while Zainura Zainon Noor (2010), worked on 'Calculating UTM Carbon Footprint: Towards Creating A Neutral Carbon Campus' and Choong, Weng Wai, et al. (2010) examined 'Energy Conservation Opportunities in Malaysian Universities'.

Many universities in Malaysia have shown initiatives to create sustainable environment through various projects and research activities (Aini Mat Said et al., 2003). Creating sustainable university in Malaysia is still at "pioneering and infancy stage" as a result of constraints by a number of barriers (Nazirah Zainul Abidin, 2009) some of which include low priority for environmental issues, lack of coordination between advocates and key constituencies as well as the lack of consensus on the understanding of the concept of sustainability and inadequate planning. Hence there is the need for the understanding of the concept of sustainability and also the need to identify a melting point for sustainability practices among the universities.

This study contributes to bridge the gap for the above need through better measuring tool for the assessment of carbon emission from energy use in the campus so as to manage energy consumption pattern in a sustainable manner and allow the setting of targets to reduce the contribution of the university CO_2 emission to global warming

This research is in line with aspiration of the Malaysian government to reduce 40% of carbon emission by year 2020 (Ho et al., 2011). The study will offer opportunity to reduce the contribution of University Teknologi Malaysia to global warming, and can be emulated by other universities. The rationale is to develop a prototype tool to ease and encourage the calculation of CO_2 among universities through inventory of carbon emission as well as present empirical information on carbon emission from energy use in the main campus of UTM.

Designing appropriate approaches for the measurement and reduction of CO_2 emission from energy use in the university campus will create a low carbon campus and ensure environmental sustainability in UTM. This may promote sustainable physical operations, and encourage inter-university cooperation among Malaysian universities in Malaysia.

The study will provide a practical framework for the assessment of the university's global warming potential which may be useful in making informed decisions towards developing and implementing sound policies and practices for

sustainable university campus. It will promote and foster the adoption of best practices in the society at large and also serve as inspiration to other universities in the country as well as encourage future research in this direction.

Quantifying CO_2 emission in the university in this manner will serve as an encouragement to corporate bodies and other universities to establish sustainable development code of practice and implement practical reporting systems which will facilitate monitoring and assessment of carbon dioxide emission over time. In addition, the study will contribute to literature on global warming issues among university campus and to low carbon campus movement and it will also assist to reduce emission intensity in Malaysia.

Finally, the study will present the picture of carbon emission from service demand areas and energy use types in UTM to assist the authority in making informed policy decisions and focusing attention on sectors or uses with high emission and also to serve as benchmark base on which emission targets may be set in order achieve low carbon campus which is a subset for sustainable campus development.

1.4 Problem Statement

The growth and expansion in the form of construction of new classrooms and better-equipped laboratories; libraries and residences to enhance the educational mission of the university, continues to accumulate carbon dioxide (CO_2) at an increasing rate (Rappaport, 2008). Similarly, investments in state of the art facilities and amenities by the university as well as bulk electronic and electrical devices that students bring to the campus also consume great deal of energy and increase energy consumption and the campus carbon dioxide emission.

The growth in sizes of universities infers high concentration of people and high traffic movement in the campus. The teaching and learning service delivery, as well as the residential and administrative activities also involve high energy demand

for lighting, cooling, and running appliances. Similarly, the movement of vehicles within the campus also consume high amount of fossil fuel energy, whose consumption results in carbon emission. This large consumption of energy in university campus results in higher CO_2 emission where aggregate emissions of the global university population may influence global warming. As a prerequisite for sustainable campus development, there is the need to correct the trend through strategies for low carbon emission.

The problem of carbon emission is more pronounced specifically in universities with large population and large spatial size, whose design requires the use of automobile to travel from one place to another within the campus. With a population of about 25,000 and a spatial size of 1157 hectares Universit Teknologi Malaysia provides an ideal case study where high energy use is required to support the activities of the large population, and also to support operations and movement within the large spatial area. The university consumes about 55,318 MWh (Megawatt hour) of purchased electricity annually from Tenaga Nasional Berhad (TNB), and has an average daily commuting population of about 14,540 vehicles; this resulted into high concentration of carbon dioxide emission which may have implication for the atmospheric greenhouse gases and global warming.

The activities and lifestyles of the university population through transportation, domestic energy use, and energy consumption pattern contribute to CO_2 emission and global warming (Caves et al. 2007). Since the majority of the campus sources of energy depend on a mixture of fossil fuel generated electricity, reducing CO_2 emission from energy use infers reducing the university campus' contribution to global warming. Preventing the carbon dioxide from entering the atmosphere, or at least reducing the magnitude will require the knowledge of the existing quantity of emission.

High financial cost of measurement is required to determine the extent of carbon emission, but the approach and process of achieving this varies and the existing tools of assessment are ambiguous in nature. The outcome is not easy to translate to action plans for planning and implementation purpose and not easily understood by administrators who lack the knowledge of environmental sciences.

Best practice approaches to university campus sustainability show collaboration and partnerships as well as the establishment of guidelines and policies to direct campus sustainability efforts of member universities. However this manner of sustainability practices is yet to manifest at appreciable scale in Malaysia. Similarly existing assessment tools and initiatives are unsuitable for Malaysian situations in view of variation in socio-economic and socio-psychological characteristics.

In order to address the phenomenal global warming issue in the Malaysian university campus there is a need to develop a tool to measure the extent of carbon emission so as to identify areas of high emission and set targets to reduce it. The collective effect and long-term influence of reducing the contribution of universities carbon emission could be vast and improve environmental quality.

Therefore there is the need to develop a suitable approach to promote environmental sustainability by reducing carbon emission from energy use among Malaysian universities. In the light of this need and the desire to realize the Eco-system Policy of UTM, this study focused on the university's global warming potentials by considering carbon emission from energy use, as a step towards university campus sustainability. The study will reduce emission and mitigate the university's contribution to global warming towards achieving the aspiration of sustainable campus through the objectives of low carbon emission in UTM.

Among the specific research problems for this study therefore are listed as follows:

i. Large population and large spatial area of university environment, causes high consumption and high energy use which depends on fossil fuel and result in high carbon dioxide emission.
ii. Absence of initiatives and partnerships to promote common sustainability goals among Malaysian universities.
iii. Lack of financial commitment to research and implement energy sustainability goals.

iv. Existing sustainability assessment tools and initiatives require expert knowledge of environmental scientist to interpret and translate to action plans by administrators for planning and implementation purposes

v. Reluctance of the university community to undertake carbon inventory because existing campus calculator are cumbersome and not suitable for reduction of carbon according to university service demand sectors.

1.5 Objectives of the Study

The issue being addressed is to develop a prototype tool for assessment of university campus carbon emission to be applied and facilitate planning and implementation of the emission target for carbon reduction so as to achieve sustainable campus. The objective of this study is to carry out an assessment of the carbon emission of UTM main campus based on energy use.

The study focused on the activities and operations of university in order to determine the extent of the emission of carbon dioxide in the campus. It also considered the sources and types of energy use in the university and the emission of carbon dioxide from the various sectors of energy consumption as a key step towards reducing carbon emission and encouraging sustainable energy practices in the university campus.

The objectives of this research are to:-

i. Identify the energy consumption pattern of the university campus.

ii. Develop a prototype tool for the assessment of carbon emission in the university.

iii. Determine the annual carbon emission of the energy use types for the university using the proposed tool;

iv. Suggest actionable initiatives to reduce CO_2 emission in the university and achieve sustainable campus.

The conceptual framework for this study is based on the fact that educational activities contribute substantially emission to the global environment resulting in global warming and universities are in best position to provide leadership for sustainable living, through reduction of carbon emission. Therefore, the study will determine the total emission within the campus based on the university activities and relevant data on energy use.

1.6 Scope of the Study

The relevant sources of energy use for this research include the energy use for mobility, energy use for domestic purpose and energy use for industrial and manufacturing purposes (Worldwatch Institute, 2008). However, this research was based on the assessment of only two (2) major sources of energy use, that is, energy use in electricity energy (for lighting cooling and to run other appliances) and energy use in transportation (movement of goods and services) within the university campus. The measurement of the third type of energy use is beyond the scope of this study mainly because the study considered energy use and carbon emission mainly from within the campus.

Therefore this study is based on the assessment of emission of greenhouse gases, particularly carbon dioxide (CO_2) generated from on-campus energy use for electricity and transport in the university campus. This involves the inventory of the actual carbon emission due to the energy use for comfort, processing, operation and movement within the university campus.

There are three (3) major scopes considered in the inventory of carbon emission of university campus: for the purpose of this study scopes 1 and 2 emissions were considered to determine the amount of carbon dioxide emission from energy use of the service sectors of UTM main campus. These are:

i. Direct Emission - UTM's bus and vehicles fleet, University shuttle Bus, all in-coming vehicles (**Scope 1**)
ii. Indirect Emission - Purchased energy / Electricity from TNB (**Scope 2**)

In view of the uncertainty of calculating Scope 3 emissions accurately it is exempted from most university carbon emission inventories and mandated to be included only by the California Climate action registry as directed by the ACUPCC. The procedure for measurement and calculation of UTM's carbon emission will depend on data that have relevance to global warming within the campus. These are mainly carbon emission from:

i. Electricity energy (combustion of fossil fuel from internally generated electricity or emission sources in the case of fuel mix from external electricity generation of university campus).
ii. Energy use in transportation (i.e. fuel combustion from movement of goods and services within the campus).

Finally, the inventory of carbon emission in UTM is based on the energy consumption pattern as describe in the university campus energy flow chart (Figure 4.3). The university was categorized into five major operational areas including four service demand areas and the transport sector based on the electricity and fuel energy use pattern and a detailed study of pattern of energy use for all he sectors constituted the scope of carbon emission for Universiti Teknologi Malaysia.

1.7 Research Questions

The primary research question for this study is how to achieve environmental sustainability in the university campus through low carbon emission. Specific sub-questions to address this main research question are as follows:

i. What measurable criteria of university campus sustainability contribute most to global warming
ii. What are the energy consumption pattern that contribute to carbon emission in the university campus
iii. What is the effective method to calculate CO_2 emission from energy use in the university campus?

vi. Can the CO_2 emission of the university campus be simulated to facilitate prediction and setting of targets for planning and implementation of emission reduction?

v. How can the practices of energy use in Malaysian universities be monitored to encourage carbon emission reduction and reduce the global warming impact of the university campus?

vi. What strategies and initiatives would reduce CO_2 emission and achieve sustainable university campus.

1.8 Significance of the Study

The development of GHG inventory is a key to achieving energy action plan (Pepple, 2009). This is significant to the sustainability of university campus because it presents the picture of the current status of carbon emissions of the university, which allows the university to make informed decisions about managing energy use and setting targets to reduce emission for the university.

For instance, additional students' population may require additional space in square meter which means additional energy needed in the buildings. This may require the development of a plan that aims at energy efficiency and more efficient building utilization. This study is significant to emission reduction or retrofits projects for the conservation of energy in existing buildings in the campus and will also be useful in determining or simulating and forecasting .carbon emission for new constructions.

The CO_2 inventory is a significant tool to measure and monitor future emission and useful device to set targets towards low carbon campus. Similarly, based on the data, a model may be developed that establishes the relationship between carbon emission, floor space and population. Based on the carbon emission report, policy decisions can be facilitated to regulate the Annual Energy Use Index (AEUI) as well as for comparisons of energy use in buildings based on increase in population or spatial space.

The CO_2 inventory for electricity and transport from this study may form the basis for future emission targets for the university and assist the university to move forward in a verifiable manner. The proposed Malaysian university campus emission tool developed in this study will assist the university to achieve sustainability, set emission reduction targets and provide the spring board for UTM to attain leadership position in achieving university campus sustainability in the region upon which further initiatives and partnerships for sustainability could be developed among Malaysian universities in general.

Furthermore, this research presented a simple method of calculating the university carbon footprint in a manner that is direct, offering clearer understanding of the magnitude of carbon emission according to service demand and use types. Not only will this facilitate clarity in making policy decision but will also offer opportunity for innovation as well as effectiveness in the implementation of strategies for emission reduction. Such innovation and experience can be shared among other universities.

The emission result in UTM will facilitate comparison and encourage emission reduction among university campuses in Malaysia, as well as reveal critical action areas of emission reduction among the service sectors as well as offer more efficient methods to reduce energy consumption among the use types, especially when the results of successes and achievement are published from where lessons could also be learnt by other universities

Furthermore, information on the basis of emission per meter square and per capita will stimulate competition among the universities, and also be very valuable for strategic decision making towards CO_2 emission reduction. The study will offer the potential for benchmarking and reduction of CO_2 in UTM in particular and stimulate awareness as well as give direction to campus energy sustainability among Malaysian universities in general.

Another significance of this study is that the technique can be used universally to examine or compare the carbon emission from energy use of other university campuses to determine their impact on global warming as well as a

measure to bench mark sustainability among the country's universities. Also the method of presenting emission according to service sectors will offer opportunities for piecemeal corrective measures for specific areas or uses.

Finally, the findings of this study will guide the administrators, faculty, staff, and students in the universities who are interested in reducing emission of CO_2, and energy cost as well as creating a sustainable campus. This research will add to the literature in the area of creating sustainable campuses and also provide a foundation for further study in campus sustainability efforts in Malaysia.

The main contribution of this research is the development of a prototype calculator which offers opportunity to quantify and reduce carbon emission from energy use. This will help university administrators to objectively tackle the main emission sources and to attain energy sustainable campus. Also the carbon emission result of UTM will enable effective planning of carbon emission reduction and encourage more efficient management of energy use in the campus as well as promote sound environmental quality

This thesis also demonstrates how an approach of measuring carbon emission of energy use for transport and electricity can be developed to reduce the global warming impact of university campuses and promote sustainability initiatives and partnership among Malaysian universities. In view of the high population and large number of universities in Malaysia, it is believed that the approach will contribute towards achieving the government's goal of reducing carbon emission in the country by 2020 and stimulate the low carbon campus movement through low carbon emission which can be attained in piecemeal among the universities

.

1.9 Delimitation of the Study

The following factors may affect the result of the study or how they were interpreted and could limit the generalizability of the study results. This study was delimited in time and space and conducted predominantly in Universiti Teknologi

Malaysia based on electricity consumption and transport survey and available data for the year 2010/2011.

The main energy sources for Malaysian universities are electricity, petrol or diesel fuel and natural gas. Since the use of natural gas in high quantities is not famous among Malaysian university campuses, this study focus on emission from electric generation and vehicular transport fuels. The study also did not consider emission from refrigerants because despite its global warming potential, emission from Aerosol, Fertilizers and other chemicals are not carbon dioxide emission from energy use, although they may have high global warming potentials their quantity is very low compared with carbon dioxide which contributes above 95% to GHG emissions.

The study did not consider the energy use in other processes and consumption such as water, waste or sewage treatment or the embodied energy in consumption of material such as paper or food on campus, which are deemed scope 3 emissions. Also, the levels and cost savings in terms of currency per CO_2 reduction was not included in the study, however future studies may consider net capital saving or annual cost analysis of energy sustainability policy or goal to produce cost saving per tCO_2 and energy cost savings for transportation and purchased electricity as well as from onsite stationary energy generation in the university.

Based on the three major globally recognized energy uses types, the study area was delimited according to categories of energy uses that emit carbon within the university. Another limitation is that some data were not included in the study, either because they were not available or because their addition or omission would not make a significant difference. For instance, the study could not retrieve data on categories of energy use for natural gas (quantities of natural gas use in UTM was not available – majority of the private kitchens and dining could not provide such data). However, a column is reserved for this data in the prototype calculator, which may be considered in subsequent research and carbon emission inventory.

Finally, the commuters transport data was delimited to vehicles on normal mid-week day from the gates of the campus while data on electricity was based on the university meter readings.

1.10 Thesis Structure

This thesis consists of seven (7) chapters. Chapter 1 is the introduction to the research and discusses the basis of the research, problem statement and the objectives and scope of the study. The second chapter looks at the review of related literature, works and researches on issues of global warming and the challenges of university campus energy sustainability. It shows the trends of university campus sustainability issues and illustrated the pattern of energy flow, explain the existing tools of measurement of carbon emission in the university campus as well as describe the process of achieving energy sustainability in university campus and also discuss the barrier for implementation of energy sustainability as well as review the collaborative approach to campus sustainability among others.

Chapter three discusses campus sustainability initiatives and best practices in university energy sustainability. It describes the regulatory bodies and tools that shape university campus sustainability, explains the practices and policy to cope with issues of energy use and physical operation in the campus environment through carbon emission reduction, mention university campus sustainability initiatives and discuss approaches and best practices approach to energy sustainability on campus. The fourth chapter of this thesis presented a detailed description of the study methodology and the process involved in conducting this research.

Also, chapter five discusses the methods of accounting for carbon dioxide emission and gave the description and the application of the Malaysian University Carbon Emission Tool (MUCET), while chapter six presented the analysis of the data and discuss the appropriate findings. Finally chapter seven concludes the thesis, providing recommendations for reducing emissions of carbon dioxide in the university campus.

REFERENCES

Abdalla, K. (2007) Energy Indicators for Sustainable Development: Country Studies on Brazil, Cuba, Lithuania, Mexico, Russian Federation, Slovakia and Thailand, United Nations Department Of Economic and Social Affairs

Adams, W.M. (2006). The Future of Sustainability: Re-thinking Environment and Development in the Twenty-first Century Report of the IUCN Renowned Thinkers Meeting, IUCN. The World Conservation Union. www.iucn.org.

Aini Mat Said, Fakhru"l-Razi Ahmadun, Laily Hj. Paim, and Jariah Masud, (2003). Environmental Concerns, Knowledge and Practices Gap among Malaysian Teachers. *International Journal of Sustainability in Higher Education*. 4 (4), 305-313.

Alasuutari, P. (1998). An Invitation to Social Research, *Sage Publication*, London.

Alshuwaikhat, H. M. & Abubakar, I. (2008). An integrated approach to achieving campus sustainability: assessment of the current campus environmental management practices. *Journal of Cleaner Production* Vol. 16**,** 1777-1785.

American Liberty Publishers (2008) IPCC GLOBAL WARMING REPORT http://www.amlibpub.com/essays/ipcc-global-warming-report.html accessed 4/3/2010

Arendt, R. (2004) Linked landscapes Creating greenway corridors through conservation subdivision design strategies in the northeastern and central United States, *Landscape and Urban Planning* Vol. 68 pp 241–269

Arrow, K. J. (2007). Global Climate Change: A Challenge to Policy, ECOMNOMIC VOICE, The Berkeley Electronic Press, www.bepress.com/ev

Arya, P. and Yesh, P. (2005) Research Methodology in Management – Theory & Case Studies Deep & Deep Publications Pvt Ltd. New Delhi

Bacani, C. (2009). Asia Challenges the U.S. for Green-Tech Supremacy, Thursday, Jun. 25, 2009. Cesar Bacani / Hong Kong. Retrieved from www.time.com on 4th February, 2010. http://www.time.com/time/world/article/0,8599,1906704,00.html accessed 12.6.2010

Balsas, C. J. L. (2001). Towards More Sustainable Transportation, Lesson learned from a teaching experiment, *International Journal of Sustainability in Higher Education*, Vol. 2 No. 4. 2001 pp 316-328

Balsas, C. J. L. (2003). Sustainable Transportation Planning On College Campuses, *Transport Policy*, Vol.10 pp 35-49

Bashir, S. (2007). *Trends in International Trade in Higher Education*: Implications and Options for Developing Countries, The World Bank, Washington D.C. USA.Education working paper series, No. 6.

Beatty, B. et al. (2002). Building Environmental Sustainability at Bowling Green State University (Executive Summary). http://www.bgsu.edu/departments/envh/ES- summary.pdf accessed on14 Nov.2010

Beringer, A. ed. (2005). *University of Prince Edward Island campus sustainability audit 2005*. Charlottetown, PEI, Canada: UPEI. Environmental Studies and Sustainability

Beringer, A. Wright, T. Malone, L. (2008). Sustainability in Higher Education in Atlantic Canada, *International Journal of Sustainability in Higher Education*, Vol. 9 No. 1. pp 48-67

Bezyrtzi, G. and Strachan, P, (2005). Carbon Footprint of the University of Strathclyde, MSc. Energy Systems and the Environment. Department of Mechanical Engineering University of Strathclyde googleusercontent.com/search?q=ca… 31/160 . accessed 12/2/2010

Blumberg, B. et al., (2008). Business Research Methods- second European edition. McGraw-Hill Higher Education. Toronto.

Boone, M. D. (2004). The way ahead: learning cafes in the academic marketplace. *Library Hi Tech,* 22**,** pp. 323-327.

Boone, M. (2006). The Campus of the Future: A meeting of the Minds, Honolulu, Hawaii - A Summary. *Library Hi Tech News.*

Bosshard, A. (2000). A methodology and terminology of sustainability assessment and its perspectives for rural planning. *Agriculture, Ecosystems and Environment 77***,** 29–41.

Bunker, G. and Stewart C (2005) Campus Sustainability Assessment, Background and Rationale, http://geog.utm.utoronto.ca/conway/ecofootprint/CSAFmainpage.html_ accessed 27.11.2010

Cambell, C. J. and Laherrere, J.H. (1998). The end of cheap oil, Scientific American, Vol. 278 No.3 pp 78-83.

Campus Planning Office (2005). Sustainability Initiatives on Campuses April 2005.http://www.fs.cornell.edu/oppd/pdf/Sustainability%20Initiatives %20on%20Campuses.pdf assessed 13.3.2011

Caves, J., Leano, M., Lee, J. and Tupper, A. (2007). Leaving Tracks: Measuring the Carbon Footprint of Rice University Students: Carbon Footprint Group, Spring.

Chambers, N., Simmons, C. and Wackernagel, M. (2000). Sharing Nature's Interest: Ecological Footprint as an Indicator of Sustainability, Earthscan Publications Ltd, London.

Chan Seong Aun (2004). ENERGY EFFICIENCY: Designing Low Energy Buildings Using Energy 10, Pertubuhan Arkitek Malaysia, CPD Seminar

Chappells H., Shove E (2005). Debating the future of comfort: environmental sustainability, energy consumption and the indoor environment, *Building Research & Information* (January–February 33(1), 32–40

Choong, W.W., Ng Sock Yen, Elia Syarafina Abdul Shakur, (2010). Energy Conservation Opportunities in Malaysian Universities, *Malaysian Journal of Real Estate, Volume 5, Number 1*

Clarke, A. et al., (2006). The Campus Environmental Management System Cycle in Practice – 15 years of environmental management, education and research at Dalhousie University, *International Journal of Sustainability in Higher Education,* Vol. 4. pp 374-389

Claussen, E. (2002). Technology and Climate Change: Sparking a New Industrial Revolution, American Institute of Chemical Engineers, New Orleans, LA.

Clayton, M and Thompson, M. (2008). Greenhouse Gas Emission Inventory, Hobart & William Smith Colleges. http//hws.edu/about/green/inventory.aspx. accessed 3rd May 2011.

Cleaves and Pasinella et al., (2009). Climate action Planning at the university of New Hampshire *International Journal of Sustainability in Higher Education,* Vol.10 No.3 pp 250-265

Cole, L. (2003). Assessing sustainability on Canadian University campuses: development of a campus sustainability assessment framework. Canada: Royal Roads University.

Connolly, F. (1999). "The human side of campus computing", *Campus-Wide Information Systems*, Vol. 16 No. 4, pp. 131-5.

Conway, T. M. et al., (2008). Developing ecological footprint scenarios on university campuses: A case study of the University of Toronto at Mississauga. *International Journal of Sustainability in Higher Education*, Vol. 9 pp. 4- 20.

Corcoran, P.B. et al., (2002) Introduction: higher education for sustainable development. *Higher Education Policy*; Vol. 15:99-103.

Cortese, A.D. (2005). Integrating sustainability in the learning community. *Facilities Manager*, Vol. 21(1) pp28-35.

Costanza, R. (2000), "The dynamics of the ecological footprint concept", *Ecological Economics*, Vol. 32, pp. 341- 5.

Cowley, S. (2008). London Centre for Nanotechnology. www.london-nano.com

Cresswell, J. (2007). Qualitative Inquiry and Research Design: Choosing among Five Traditions, 2nd edition Sage Publication, Thousand Oaks, California.

Czypyha, B. (2004). Greening Pearson Project *Sustainable Campus Planning* ES420 Major Project 2003-2004, Prepared by Balance Eco-Consultants, for: Pearson College and Royal Roads University.

Dahle, M. & Neumayer, E. (2001). Overcoming barriers to campus greening A survey among higher educational institutions in London, UK. *International Journal of Sustainability in Higher Education,* Vol. 2 pp. 139-160.

Dawe, G.F.M., Vetter, A. and Martin, S. (2004). "An overview of ecological footprinting and other tools and their application to the development of sustainability process: audit and methodology at Holme Lacy College, UK", *International Journal of Sustainability in Higher Education*, Vol. 5 No. 4, pp. 340-71

Deakin, M. et al. (2002). The assessment of sustainable urban development. *Building Research & Information* 30**,** 95–108.

Dorsey, B. (2005). Mass Transit Trends And The Role Of Unlimited Access In Transportation Demand Management, *Journal Of Transport Geography, 13, pp235-246*

Dresner, S. (2008). The Principles of Sustainability, 2nd ed. London. EARTHSCAN

Eagan, D. J. et al. (2008). Higher Education in a Warming World. The Business Case for Climate Leadership on Campus National Wildlife Federation's CAMPUS ECOLOGY www.nwf.org/CampusEcology/Business Case assessed online July 2009.

Elderkin. R. (2007). A First Step Toward A Climate Neutral Pomona College: Greenhouse Gas Emissions Inventory and Recommendations for Mitigating Emissions *Pomona Campus Climate Challenge 27 April 2007*

Environmental Sustainability Index (ESI) (2005). *Benchmarking National Environmental Stewardship* Yale Center for Environmental Law and Policy, Yale University. Center for International Earth Science Information Network, Columbia University. In collaboration with: World Economic Forum Geneva, Switzerland Joint Research Centre, European Commission. ISPRA, Italy

Fellows, R. and Liu, A. (2003). Leadership Style and Power Relations in Quantity Surveying in Hong Kong. *Construction Management and Economics*, Volume 21, Number 8, pp. 809-818

Filippin, C. (2000). Benchmarking the Energy Efficiency and Greenhouse Gases Emission of School Buildings in Argentina. *Building and Environment* Vol. 35 pp 407-414

Flint, K. (2001). Institutional ecological footprint analysis case study of the University of Newcastle, Australia. *International Journal of Sustainability in Higher Education*, Vol. 2 No. 1, pp. 48-62.

Fong, W et al, (2008). Energy Consumption and Carbon Dioxide Emission Considerations in The Urban Planning Process in Malaysia. *Journal of the Malaysian Futures.* Vol. 38(5):633-7.

Ganesan, V. (2010). Philips sheds more light on energy efficiency, *Business Times*, Wednesday, September 15, 2010, (Rssmobileemail Alertwidgetdigital Edition).

Getzner, M. (1999). *Weak and strong sustainability indicators and regional environmental resources* Environmental Management Environmental Management and Health1 pp70-176.

Glasby, G. P. (1995). Concept of sustainable development: a meaningful goal? *The Science of the Total Environment*, 159, 67-80

Glasson, J. (2009). Developing a Sustainable UTM Campus Initiative— Some First Steps. *Presentation and Discussion led by Prof. John Glasson*, Oxford Brookes University, and Visiting Professor at Curtin University (Perth, WA). October 30, 2009, Senate Hall, Universiti Teknologi Malaysia.

Gobi, K. A. (2009). *Perception of UTM's Community Towards Sustainable Campus*. Masters of urban Planning, Universiti Teknologi Malaysia.

Graedel, T. E. (2002). Quantitative Sustainability in a College or University Setting. *International Journal of Sustainability in Higher Education*, Vol. 3 pp 346-358.

Green, C. (2008). Global warming; Copenhagen Consensus 2008 *Perspective Paper* Copenhagen Consensus Center assessed February16th 2010.

Green Energy Office (GEO Building) Exploring Green Technology in Building www.ptm.org.my/ptm_building

Green League (2010). Frequently Asked Questions | People & Planet, http://peopleandplanet.org/greenleague/faq2010. Accessed on 11/29/2010

Griffiths, A. (2002), *Ecological footprint analysis: Swansea (University of Wales, B.Sc.* Dissertation, University of Wales, Swansea.

Hammond, A. et al. (1995), Environmental Indicators, a Systematic Approach to Measuring and Reporting on Environmental Policy Performance in the

Context of Sustainable Development, *World Resources Institute*, Washington, DC.

Hardy, D. (2008). Cities that don't cost the earth. Published by Jon Land for TCPA in Housing and also in Communities, Local Government Monday 2nd June 2008.

Hare, W. L. (2009). A Safe Landing for the Climate, *State of the World into a Warming World*, 2009 Report, Worldwatch institute, www. worldwatch.org/ *stateoftheworld. Accessed July 7, 2010*

Harmon, M, (2006). Chico STATEMENTS, a magazine from California State University, Chico online edition, spring 2006. Accessed online March 20th 2009.

Harvey, B. (2006). Frost Sustainable Campus Initiative. Accessed online 14 November, 2008.

Heather, C. and Shove E. (2005). Debating the future of comfort: environmental sustainability, energy consumption and the indoor environment, *Building Research & Information* (January–February 2005) 33(1), 32–40

Hennessey, K. (2000). Climate Change, CSIRO, Melbourne.

Hien and Jusuf, (2008). GIS-based greenery evaluation on campus master plan *Landscape and Urban Planning*, Vol.84 pp 166–182

Ho, C. S. (2008). Pathway to low carbon society (LCS): the case of Malaysia. The 3rd International Seminar. Towards Establishing Sustainable Planning and Governance. Sustainable Urban Development Institute, *Institute of Planners*, Vol. VI, 99-128

Ho, et al. (2011). Putrajaya Green City 2025 baseline and preliminary study. March 2011.

Hone, D. (n.d.) Shell Climate Change, Pathways to 2050. Group Climate Change Adviser, Shell International Ltd. www.ipieca.org/activities/climate_change/downloads/workshops/27sept_06/Session_2/Hone.pdf. Accessed online. June2010.

IEA Energy Statistics, CECD/IEA (2008). (www.iea.org/statistics/index.htm). Accessed 2009.

International Atomic Energy Agency (IAEA), International Energy Agency (IEA), (2001). *Indicators for Sustainable Energy Development*, presented at

the Ninth Session of the Commission on Sustainable Development, 16-27 April 2001, New York.

International Atomic Energy Agency (IAEA) (2007). *Energy Indicators For Sustainable Development: Country Studies On Brazil, Cuba, Lithuania, Mexico, Russian Federation, Slovakia and Thailand*, United Nations Department Of Economic and Social Affairs, New York,

ISCN Charter, (2008). *International Sustainable Campus Network Conference, Sustainable Campus Design Guidelines*, Zurich, Switzerland, http://www. Novatlantis.ch

International Sustainable Campus Network ISCN (ISCN) (2009) Novatlantis - Sustainability at the ETH domain www.novatlantis.ch

IPCC 2001-UNEP (2001) IPCC Special Report on Emissions Scenarios GRID-Arendal. http://www.grida.no/publications/other/ipcc_sr/?src=/climate/ipcc/emission/050.htm Accessed online, 2010.

Intergovernmental Panel on Climate Change (IPCC), (2007). "Climate Change 2007: The Physical Science Basis. Summary for Policymakers." *Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Feb. 2007.

Isham, J. T. et al., (2003). *Carbon Neutrality at Middlebury College: A Compilation of Potential Objectives and Strategies to Minimize Campus Climate Impact*. Draft Prepared For the Carbon Reduction Initiative at Middlebury College.

James, M. R. (2009) *Going Green: A Comparative Case Study of How Three Higher Education Institutions Achieved Progressive Measures of Environmental Sustainability*, Ph.D. Thesis. The University of South Dakota.

James, S. (2003). Eco-municipalities: Sweden and the United States: A Systems Approach to Creating Communities. Retrieved on: 31.5.2010

Jiusto, J. S. (2008). An indicator framework for assessing US state carbon emissions reduction effort (with baseline trends from 1990 to 2001), Energy Policy 36 (2008) 2234-2252

Jiusto, J. S. (2003). Spatial Indeterminacy and Power Sector Carbon Emissions Accounting. *Ph.D. Thesis.* Faculty of Clark University, Worcester, Massachusetts,

Kainuma, M. et al. (2007). Aligning Climate and Sustainability-Scenarios, modeling and policy analysis. *Center for Global Environmental Research, National Institute for Environmental Studies, Japan*. ISSN1341-4356 CGER-1072-2007

Kainuma, M. et al. (2008). Global Greenhouse Gas Emissions Reduction Potentials and Mitigation Costs in 2020 – Methodology and Results. *Center for Global Environmental Research, National Institute for Environmental Studies*, Japan. ISSN1341-4356 CGER-1081-2008

Kahler, S. (2003). The ripple effect: how one dorm room can affect a university's energy use. *International Journal of Sustainability in Higher Education*, Vol. 4 No. 3, pp. 230-238.

Kamp, L. (2006). Engineering Education in Sustainable Development at Delft University of Technology, *Journal Of Cleaner Production*, Vol. 14 928-931

Karol, E. (2006). Using campus concerns about sustainability as an educational opportunity: a case study in architectural design Journal of Cleaner Production Vol. 14 pp 780-786.

Kelly, S. (2010). Frost Sustainability Coordinator. Frost Sustainable Campus Initiative. http://www.flemingc.on.ca/index.cfm/go/fleming/sub/fsci.cfm accessed on 14 Nov.2010

Kerr, R.A. (2000). USGS optimistic on world oil prospects, Science, Vol.268, pp1305-12

Khedun, P. et,al. (2009). Improving hydrologic sustainability of Texas A&M university campus, *Proceedings of World Environmental and Water Resources Congress 2009 - World Environmental and Water Resources Congress 2009: Great Rivers*, v 342, p 1238-1247.

Klugman, J. (2009). Human Development Report 2009. Overcoming barriers: Human mobility and development. UNDP.

Knox, L.W. (2002).*The Christian Science Monitor* May 21, 2002 edition.

Levine, D. (2008). Campus climate action in the United States. *Encyclopedia of Earth.* The Canada Institute of the Woodrow Wilson International Center for Scholars.

Lincoln, S. F. (2006). *Challenged Earth an Overview of Humanity's Stewardship of Earth*. London: Imperial College Press.

Lipsett, A. (2007). University ranking don't measure up *Mortarboard Guardian Unlimited.* November 8, 2007 12:01AM, http://education.guardian.co.uk/ home, accessed on July, 12, 2008.

Low, S. T. (2008). *Energy Management Key Practices For Universities in Malaysia*. Master of Science (Facilities Management), Faculty of Geo-information Science and Engineering, Universiti Teknologi Malaysia.

Lourdel, N. Gondran, N. Laforest, V. and Brodhag C. (2005). Introduction of sustainable development in engineer's curricula problematic and evaluation methods. *International journal of sustainability in higher education,* Vol. 6, No3.

Lozano, R. (2006). Incorporation and institutionalization of SD into universities: breaking through barriers to change, *Journal of Cleaner Production* 14

Lukman, R. and Glavic, P. (2007). What Are the Key Elements of a Sustainable University? *Clean Techn Environ Policy* Vol. 9:103–114

Lukman, R. (2009). Towards greening a university campus: The case of the University of Maribor, Slovenia. *Resources, Conservation and Recycling*, Vol. 53, No. 11, p 639-644,

National Energy Foundation NEF | Information: Organisations - Simple Carbon Calculator http://www.nef.org.uk/greencompany/ CO_2 calculator.htm - accessed 10/17/2010

Makenzie, G. Powell J. and Usher R. (1997). *Understanding Social Research Perspectives on Methodology and Practice*, Falmer Press, London.

Mason, I. G., Brooking, A. K., Oberender, A., Harford, J. M. & Horsley, P. G (2003). Implementation of a zero waste program at a university campus *Resources, Conservation and Recycling Vol.* 38 pp 257-269.

Marans, R. W. and Edelstein J. Y (2010). The human dimension of energy conservation and sustainability: A case study of the University of Michigan's energy conservation program. *International Journal of*

Sustainability in Higher Education 11:1, 6-18 online publication date: accessed1-Jan-2010.

Materu, P. (2007). *Higher Education Quality Assurance In Sub-Saharan Africa-* status, challenges, opportunities, and promising practices, Africa Region Human Development Department, The World Bank, Washington D.C. World Bank Working Paper No. 124.

Mayer, A. L, (2008). Strengths and weaknesses of common sustainability indices for multidimensional systems, *Environmental International Vol. 34, 277-291.*

Mcintosh, M., Gaalswyk, K., Keniry, J., & Eagan, D. (2008). Campus Environment 2008: A National Report Card on Sustainability in Higher Education. National Wildlife Federation.

McNeilly, L. (2008). UC Berkeley Campus Sustainability University of California

Meng, L.L (2007). *Kampus Sejahtera Kampus Lestari: the genesis for a sustainable campus,* A Consultative Document, Corporate & Sustainable Development Division, Universiti Sains Malaysia

Mohammed S.F. (2006). *Improving Construction Site Management Practice through Knowledge Management*. PhD Thesis Universiti Teknologi Malaysia, Malaysia.

Morrow D, and Rondinelli D. (2002). Adopting corporate environmental management systems: motivations and results of ISO 14001 and EMAS certification. European Management Journal; Vol. 20(2):159- 71.

National Energy Foundation (NEF) Information: Organisations - Simple Carbon Calculator http://www.nef.org.uk/greencompany/ CO_2 calculator.htm - accessed 10/17/2010

NaturalGas (2010). Natural Gas and the Environment. www.naturalgas.org/environment/naturalgas.asp assessed 17.10.2010.

Nazirah Zainul Abidin, (2009). Sustainable Construction in Malaysia –Developers' Awareness. World Academy of Science, *Engineering and Technology*, 53, 807- 814.

Newman L. (2006). Change, uncertainty, and futures of sustainable development.

Newton, L.H. (2003). Ethics and Sustainability: Sustainable Development and the Moral Life. Upper Saddle River, N.J.: Prentice Hall.

Nilsson, J. et al., (1998). Greening of a Campus Restaurant at Stockholm university: Sustainable Development Audits by Means of the SDR Methodology, *Journal of Management*, Academic Press Limited

Nurulain. Binti A. Jalal (2010). *Factors of Sustainability for UTM Sustainable Campus Initiatives.* Bachelor of Civil Engineering, Universiti Teknologi Malaysia

Olson, R. (2007). University Of Wisconsin - Whitewater. Campus Facility Maintenance Cygnus Business Media Fall 2007, 4(3), 10-12. Retrieved January 23, 2008, from ABI/INFORM Trade & Industry database. (Document ID: 1381902381).

Ott, K. (2003). The Case for Strong Sustainability. In: Ott, K. & P. Thapa (eds.) (2003). *Greifswald's Environmental Ethics.* Greifswald: Steinbecker Verlag Ulrich Rose. ISBN 3931483320. Retrieved on: 2010.5.31

Park, K. et al., (2003) Quantitative Assessment of Environmental Impacts on Life Cycle of Highways, Journal of Construction Engineering and Management, Vol. 129, No.1. http://www.ascelibrary.org accessed 01 Nov 2010

Parker, A. (2007) Creating A "Green" Campus, Bioscience, Vol. 57, No. 4, Pages 321 – 321 (doi:10.1641/B570406)

Parrott, J. (2004) Sustainable Development Past and Present: Patrick Geddes Lecture, *Sustainable Development Commission*, 23rd November 2004

Pepple, K. D. 2009. Analysis of Mobile Emissions Attributable to the University of Houston For The Development Of Strategic Sustainability Goals. Ph.D. Thesis. University of Houston

Pew Center on Global Climate Change 2006. What's being done in the states (www. Pewclimate.org/ What_s_being_done/in_the_states/index.cfm) accessed 2009.

Piper, J.M. (2002) CEA and sustainable development: evidence from UK case studies. Environmental Impact Assessment Review. Vol.22:17-36.

Pope, J., Annandale D., Morrison-Saunders 2004). Conceptualising Sustainability Assessment, Environmental Impact Assessment Review, Environmental Impact Assessment Review Vol. 24, pp 595–616

Qiang, W. (1997), Estimates Of CO_2 Emissions in Shanghai (CHINA) in 1990 and 2010' *Energy* Vol. 22, No. 10, pp. 1015-1017,

Quaddus, M.A. and Siddique M.A.B. (2001) Modeling sustainable development planning: a multicriteria decision conferencing approach. *Environment International*; Vol. 27:89-95.

Rappaport, A. 2008. Campus Greening: Behind the Headlines. *ENVIRONMENT*, Science and Policy for Sustainable Development, Vol. 50 No.1

Readings, B (1997). *The University in Ruins*, HTML\Harvard University Press.mht. accessed February, 2008

Rees, W. (2003). Impending sustainability? The Ecological Footprint of Higher Education, *Planning For Higher Education* Vol. 31(3) 88-98)

Renn, O. et al. (1998). How to Apply the Concept of Sustainability to a Region; *Technological Forecasting and Social Change* Vol.58, 63–81

Riddell, W. et al. (2009). Assessing carbon dioxide emissions from energy use at a university. *International Journal of Sustainability in Higher Education,* Vol. 10 pp. 266-278.

Roorda, M. (2000). Auditing sustainability in engineering education with AISHE, ENTRÉE 2000 Proceedings, EEE Network, Brussels, pp. 13-30.

Rosan, R.M. (2002). The Key Role of Universities in Our Nation's Economic Growth and Urban Revitalization- *Urban Land Institute*, http://experts.uli.org/Content/WhosWho/officer/Rosan/Rosan_C7.htm. accessed December 2009.

Sathiendrakumar, R. (2003) Greenhouse emission reduction and sustainable development International Journal of Social Economics Vol. 30 No. 12, 2003 pp. 1233-1248.

Schmidt, M. 2009. Carbon accounting and carbon footprint – more than just diced results? *International Journal of Climate Change Strategies and Management,* Vol. 1 pp. 19-30.

Sekaram U. (2003). Research Methods for Business - a skill building approach 4th ed. John Wiley & Sons (Asis) Pte Ltd. Singapore.

Sharp, L. (2002). Green Campus: The Road From Little Victories To Systemic Transformation, *International Journal of Sustainability in Higher Education* Vol.3. No.2. 2002.

Shriberg, M. (2002). Institutional Assessment Tools for Sustainability in Higher Education: Strengths, Weaknesses, and Implications for Practice and Theory. *Higher Education Policy*; Vol. 15:153-67.

Shriberg, M. & Tallent, H. (2002b). Beyond Principles: Implementing the Talloires Declaration.

Shriberg, M. (2001). Towards Sustainable Management: the University of Michigan Housing Division's approach, *Journal of Cleaner Production*, 10. pp 41-45.

Sihabuddin, S. S. (2009). Methodology for estimating emissions in underground utility construction operations, *Journal of Engineering, Design and Technology*, Vol. 7 No. 1, pp. 37-64

Simkins, G and Nolan, A. (2004). *Environmental management system in universitie*s. Occasional paper for the environmental association for universities and colleges (EAUC).

Spiller, R. (2000). *The challenge of greenhouse gas emissions*. An Industry Guide. New Zealand Business Council for Sustainable Development.

Stern, Sir Nicholas (2007). *The Economics of Climate Change*. Cambridge, UK: Cambridge University Press. Available at: http://www.hm-treasury.gov.uk/Independent_Reviews/stern_review_economics_climate_cha

*S*tewart, C. (2005). Ecological Footprint Progress Report, University of Toronto Mississauga. http://geog.utm.utoronto.ca/ecofootprint/doc/efprogressreport2005.pdf.

Stimson, M. (2010). University Sustainability Initiatives: University Files Ambitious Climate Action Plan - www.mum.edu/sustain/climate_action.html accessed on 17th September 2010.

Stulz, R. (2008). Sustainable Campus Design Guidelines ISCN Charter. *ISCN International Sustainable Campus Network.*

Summit on Sustainable Development (WSSD), Johannesburg (2002).

Thavasi, &. Ramakrishna, (2009). Time Magazine www.time.com (Retrieved online July 2009)

Toor, W. & Spenser, W. (2004). Transportation and Sustainable Campus Communities: Issues, Examples, Solutions, *Havlick*, Island Press, Washington, D.C.

U.S. Environmental Protection Agency (2005). Greenhouse Gas Emissions from a Typical Passenger Vehicle. Emission facts. Office of Transportation and Air Quality. EPA420-F-05-004

U.S. Environmental Protection Agency (2006). Greenhouse Gas Emissions from the U.S. Transportation Sector, 1990-2003.Washington, DC. www.epa.gov/otaq/climate.htm. accessed 2009

ULSF (2008). Talloires Declaration: Report and Declaration of the Presidents Conference (1990) www.ulsf.org/programs_talloires.html accessed May 2009

United Nations (UN) (2000). United Nations Millennium Declaration, General Assembly, A/RES/55/2, New York.

United Nations (UN), (2002). Report of the World Summit on Sustainable Development, A/CONF.199/20, New York.

United Nations Department of Economic and Social Affairs (UNDESA), (2001). *Indicators of Sustainable Development: Guidelines and Methodologies*, Second edition, New York. United Nations Development Programme (UNDP), United Nations Department of Economic and Social Affairs (UNDESA), World Energy Council (WEC), 2000. *World Energy Assessment: Energy and the Challenge of Sustainability*, New York.

University of California, Santa Cruz (UCSC), (2006). The Blueprint for a Sustainable Campus. 5th Annual Campus Earth Summit. Student Environmental Center. www.ucscsec.org

UNSD (2009). Millennium Development Goals Indicators database. United Nations, Department of Economic and Social Affairs, Population Division, World Population Prospects: The 2008 Revision, New York, 2009 (advanced Excel tables). UNSD Demographic Yearbook. http://mdgs.un.org/unsd/mdg/Data.aspx. assessed July 2011.

Velazquez, L. et al. (2006). Sustainable University: what can be the matter? *Journal of Cleaner Production*; Vol. 14:810-9.

Venetoulis, J. (2001). "Assessing the ecological impact of a university: the ecological footprint for the University of Redlands", *International Journal of Sustainability in Higher Education*, Vol. 2 No. 2, pp. 180- 97.

Vera, L., Langlois, H. and Rogner, H. (2006). *Indicators for Sustainable Energy Development* International Atomic Energy Agency (IAEA),

Wackernagel, M. and Rees, W. (1996), Our Ecological Footprint, New Society Publishers, Gabriola Island.

Watkins, K. et al. (2008). Human Development Report 2007/2008. *Fighting Climate Change: Human Solidarity in a Divided World.* USA: United Nations Development Programme (UNDP).

Watkins, K. et al. (2007b). Human Development Report 2007/2008. United Nations Development Programme (UNDP) 1 UN Plaza, New York, New York, 10017, USA.

Webometrics (2009). Catalogue of World Universities. Available online: http://www. webometrics.com (February 2009)

Weenen, H. V. (2000). Towards a vision of a sustainable university. *International Journal of Sustainability in Higher Education*, Vol. 1 No. 1, pp. 20-34.

White, S. S. (2003). Sustainable Campuses And Campus Planning. Experience from a classroom case study at the University of Kansas. *International Journal of Sustainability in Higher Education*, Vol. 4 No. 4**,** pp. 344-356.

Willson, R. and Brown, K. (2008). Carbon Neutrality at the Local Level: Achievable Goal or Fantasy? *Journal of the American Planning Association* Vol. 74, No.4 pp 497-504.

WCED (1987). Our Common Future, Report of the World Commission on Environment and Development, World Commission on Environment and Development, 1987. Published as Annex to General Assembly document A/42/427, Development and International Co-operation: Environment August 2, 1987. Retrieved, 2010.11.14

WCED (1987). Our Common Future: The Brundtland Report, Oxford University Press, Oxford.

World Development Report (2010). Development and Climate Change. World Bank (2009) ISBN: 0-8213-7987-9

Worldwatch Institute Report (2008). *Making Better Energy Choices,* www.worldwatch.org

Worldwatch institute Report (2009). *State of the World,* www.worldwatch.org

Wright, T. S. A. (2002), Definitions and frameworks for environmental sustainability in higher education, International *Journal of Sustainability in Higher Education,* Vol: 3, No.3

Yang, C et al., (2009). Meeting an 80 % reduction in greenhouse gas emissions from transportation by 2050: A case study in California. Transportation Research Part D 14 pp 147-156

Yeoh, P. (2008). Is carbon finance the answer to climate control? *International Journal of Law and Management,* Vol. 50 pp. 189-206.

Zainura Zainon Noor, (2010). Calculating UTM Carbon Footprint: Towards Creating a Neutral Carbon Campus. Report. University Teknologi Malaysia.